

NIST Handbook 105-8

(Notes and Decision Processes)

Specifications and Tolerances for Field Standard Weight Carts

Historical Background

The use of Field Standard Weight Carts in testing large capacity scales is a complex and sometimes emotional issue. Weight cart use permits one or two individuals to test a large capacity scale in a fraction of the time previously required by previous methods of testing. They allow the scale inspector or technician to load the weights required for the test into the weight cart and then position it as needed on the scale deck, with a single handling of the weights. This results in a tremendous time savings, which converts to a tremendous savings in manpower costs and downtime for the scale operator.

Additionally, due to the minimal amount of time during which the scale mechanism must be loaded, the effects of drift on the measurements are minimized. Most large capacity scales, for which weight cart use might be appropriate, are loaded from zero load to the typical load being weighed, in mere seconds. The load indication is recorded and the load removed with the total time loaded being much less than 5 minutes. Using the old method of large capacity scale testing, the time from the application of the first weight until the last weight is loaded might approach 20 minutes, with off loading of the scale taking a similar time period. The time for a single section test can be as long as one hour. This contributes to drift errors in the scale indications, resulting in increased inaccuracies.

Weight Cart Use

Weight carts have been in use in some form since the early 1970's, and in recent years the use of weight carts has increased dramatically until there are now in excess of 350 weight carts in use in the United States. However, these weight carts have not been built to a standard design or specification, which has contributed to problems with the stability of the mass of the weight carts. Weight cart issues were so controversial that the National Conference on Weights and Measures (NCWM) adopted a policy that weight carts were not to be used as field standards.

Historically, the National Conference on Weights and Measures (NCWM) Publication 3, Section 3.2.15 states the following:

"Field standard test weights (weight carts) are being used to test vehicle scales. These weight carts are powered by liquid fuel which is consumed during the conduct of the test. It is impossible to maintain these devices within the tolerance limits (1/10 000) as required by Handbook 105-1 or within 1/3 of the smallest tolerance applicable as required by Handbook 44 and are therefore inappropriate as Standard Weights."

This policy was proposed by the S&T committee and approved in 1980. Item 309-2, p. 237.

Additionally, calibration laboratories have had no direction concerning the required testing

processes or equipment for calibrating the weight carts. These problems have led to some Weights and Measures jurisdictions forbidding the use of weight carts when testing scales. They have also contributed to large potential errors in the scale calibration process.

Standard Development Begins

A work began to draft specifications and procedures for weight cart design, calibration and use. Ronald Balaze, Michigan Department of Agriculture and Georgia Harris, NIST Office of weights and measures developed and circulated the first draft document for comment in 1998. This specification was originally to be included as an appendix in NIST Handbook 105-1, Specifications and Tolerances for Field Standard Weights (NIST Class F). Also from that work, recommendations for how to proceed with the weight cart issue were developed. Comments were collected, however, it was eventually decided that including the weight carts in HB105-1 was inappropriate as the liquid fueled weight carts are not typically capable of meeting and holding Class F tolerances during use. Val Miller, NIST office of Weights and Measures, using the original draft document and the subsequent comments, prepared Draft 2 of the specification. A survey of the weight cart community was also initiated to accumulate specific information concerning current weight cart designs and the number of weight carts in use.

Weight Cart Working Group Established

Following recommendations developed from comments about the initial draft, NIST Office of Weights and Measures formed a working group of twelve individuals with an interest in weight cart standardization, and with a varied experience in field and metrology laboratory work, weight cart manufacturing and scale manufacturing and installation. The group included state standards laboratory personnel who had worked as field inspectors prior to moving into the standards laboratory, state weights and measures directors, scale manufacturers and weight cart manufacturers. This group, because of their varied experience and current positions, was quite qualified to address the weight cart design calibration and use requirements. Eight members of the Weight Cart working Group met at the NIST Gaithersburg Campus in September 2001 to evaluate Draft 2 and to address additional concerns that had been addressed. Comments and concerns of the remaining members were delivered to the meeting electronically.

The working group included:

Val Miller, NIST Office of Weights and Measures (Chair)

Bruce Adams, Minnesota Department of Commerce

Ronald Balaze, Michigan Department of Agriculture

Sid Colbrook, Illinois Department of Agriculture Bureau of Weights and Measures

John Dewald, Tiffin Loader Crane

L.F. Eason, North Carolina Department of Agriculture and Consumer Services

David Ehrnschwender, Fairbanks Scales, Inc.

Georgia Harris, NIST Office of Weights and Measures

Emil Hazarian, Los Angeles County Agricultural Commissioner Weights and Measures Department

John Holt, Kanawha Scales and Systems, Inc.

Tom Schafer, Idaho Department of Agriculture Bureau of Weights and Measures

Richard Suiter, NIST Office of Weights and Measures

At the beginning of this document it was stated that the use of weight carts is a complex issue. Field class standards must be stable, durable and capable of meeting the requirements of the testing processes in which they will be used. Because weight carts are used in the testing of scales, the most critical feature is having a stable mass. Second most important, is that the weight cart must not damage the scale being tested.

The working group knew that because of wide acceptance of weight cart use due to economic factors, and the improved testing process, weight carts were not going to be eliminated. So the decision was made to evaluate the existing weight carts, examine the short comings of each design and to address in the best way possible the issues that contribute to mass errors. NIST Handbook 105-8, Draft 3, was developed to outline and document the minimum design requirements that would minimize to the greatest extent possible those potential error sources. Additionally, the working group submitted to the NCWM, through its regional organizations, a proposed change to the NCWM policy against weight cart use. The proposed policy change reads as follows:

"Field standard test weights (weight carts) are being used to test vehicle scales. Some carts are electrically powered, and many of these weight carts are powered by liquid fuel which is consumed during the conduct of the test. NIST Handbook 105-8, "Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures. 8. Specifications and Tolerances for Field Standard Weight Carts" provides design criteria for greater cart stability. Following recommended methods for calibration and use will also enhance their use as field standards. In 1980, the adopted NCWM policy stated that these carts were inappropriate as standard weights. The proliferation of weight cart use has provided data on which to demonstrate that the benefits of weight cart use outweigh the disadvantages associated with their potential instability for use in scale testing."

The Weight Cart Working Group, using Draft 2, and their wide experience in scale testing, developed what is now designated NIST Handbook 105-8 Draft 3, "Specifications and Tolerances for Field Standard Weight Carts". This draft was posted on the NIST OWM State Laboratory Program web page for comment.

At the 2002 NCWM Annual Meeting in Cincinnati, Ohio, the Conference approved the following statement as part of their Standards and Technology agenda:

"Field standard test weights (weight carts) are being used to test vehicle scales. Some carts are electrically powered while many other weight carts are powered by liquid fuel, which is consumed during the conduct of the test. Following recommended methods for calibration and use will enhance their use as field standards. In 1980, the adopted NCWM Policy stated that these carts were inappropriate as standard weights. The proliferation of weight cart use has provided data on which to demonstrate that the benefits of weight cart use outweigh the disadvantages associated with their potential instability for use in scale testing."

This statement was proposed by the S&T committee and approved in 2002. Voting Item 360-4.

What HB 105-8 is NOT!

The purpose of HB105-8 is not to direct the engineering decisions involved with the construction of a weight cart; the manufacturer maintains engineering responsibility. Rather, HB105-8 establishes the metrologically sound criteria that the engineer must incorporate in his/her engineering decisions as the design of the cart is developed. Each section of the standard addresses a specific design issue identified as being important to ensure the metrological stability of the weight cart or to ensure that the scale under test will not be damaged by use of the weight cart.

The Future

It was recognized that weight carts currently in service may not meet all of the requirements of NIST HB 105-8 and that it would not be feasible to alter them so that they were fully compliant, without causing unreasonable economic hardship on the owning organization. Thus, only those design criteria determined to be most critical to the mass stability of the weight cart were designated retroactive. Retroactive design issues include tires, batteries, tolerances and fuel tanks.

Current thinking is that all new weight carts manufactured after January 1, 2004 must comply with the specifications and tolerances of NIST Handbook 105-8. Additionally, all weight carts in service at the time of implementation of this standard, must comply with the retroactive requirements of this standard by December 31, 2005 to remain in service. These dates may be adjusted depending on responses from weight cart users and manufacturers.

Discussion of NIST HB 105-8 Draft 3:

- 1.1 **Field Standard Classification:** Because the weight cart is used as a calibration standard in the field for testing commercial weighing devices the weight carts will be considered 'Field Standards', but are not 'NIST Class F Field Standards' as they will not be required to maintain the tolerances specified in NIST Handbook 105-1 for Class F weights.
 - 1.2 **Retroactivity:** Certain design criteria were determined to be of such critical nature that they were designated as being Retroactive requirements and include issues dealing with tires, batteries, tolerances and fuel tanks.
 - 1.3 **Safety considerations:** A list of potential safety issues are identified, but must not be considered to be an exhaustive listing of ALL potential safety concerns. As stated, the manufacturer and user must evaluate the design and use of the weight cart and develop such safety documentation/requirements as may be applicable.
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- 4 **General Specifications:**
 - 4.1 **Weight**
 - 4.1.1 **Nominal Empty Weight:** The use of 500 lb increments was selected to minimize number of weights that would be required to be handled to perform a substitution calibration of the weight cart. Large weights like those normally used as standards in weight cart calibrations are most commonly procured in 500 lb or 1000 lb blocks. Odd

weights between the 500 lb increments require the use of additional weights which increase the possibility of back injury from handling 50 lb and 100 lb weights. Additionally, the uncertainty attributed to the mass standards is typically minimized by keeping the number of standards required to the fewest number possible.

Also, these nominal weights were established with the idea the standards used for the scale test should as much as possible be kept to multiples of the weights carried in the weight cart. The original idea was that the weight cart should always be used in combination with a minimum weight load at least four times the nominal weight of the weight cart. The current draft has been modified to allow the use of an empty weight cart, but the weight cart must have demonstrated mass stability by remaining within the tolerance for several calibration cycles.

The actual weight of a properly serviced cart, with empty adjustment cavities must be between 50 lb and 100 lb less than the nominal weight of the weight cart. This will allow the adjustment of the weight cart in the event of modification, or major component change out, without requiring additional modifications to bring the weight back to the nominal value.

- 4.1.2 **Weight and size restrictions:** The laboratory performing the calibration of the weight cart may impose maximum size and weight restrictions due to the limited capabilities of their equipment and facility. The prospective user of a weight cart must ensure that calibration support, meeting the requirements of this handbook is readily available. Failure to do so may result in additional expense traveling to a laboratory that is able to provide calibration support.
- 4.2 **Materials:** It was decided that at the present time steel should be the predominant material for the construction of weight carts. This is due to its relatively high density, ready availability, good workability, and stability. Rubber hoses and power cords are required for some designs, but the amounts of these materials should be minimized.
- 4.3 **Workmanship, Finish and Appearance:** Paints used on weight carts must have the same basic qualities as those used on NIST HB 105-1 Class F weights. Chip resistance is of utmost importance as the mass of the weight cart can be changed significantly by loss of paint on the large surface area of a weight cart.
- 4.4 **Design:** The representative designs shown in Figure 1 are basic designs currently in use. Other designs may be suitable and should be submitted to NIST OWM for approval of the suitability of materials and construction techniques for *metrological* soundness. Some weight carts currently in service were constructed so that water and other contamination are trapped in or on the weight cart structure contributing to mass instabilities. NIST OWM will assist the manufacturer in avoiding design and construction deficiencies that would make the weight cart mass unstable but does not wish to diminish in any way the manufacturer's responsibility for design integrity and safety.

- 4.5 **Identification Plate:** The weight cart must be permanently and uniquely identified.
- 4.6 **Power:** Most any currently available motive power source may be used, though consideration must be given to the mass stability of the power source selected. Weight carts powered by an electric motor have proven to have the most stable mass, typically meeting and maintaining NIST Class F tolerances, but there are concerns and limitations involved. Electricity to power an electrically powered weight cart must be delivered to the cart via an umbilical cord from a generator or ground power source. This necessitates the frequent making and breaking of high voltage, high current power connections. Additionally, these weight carts have been somewhat limited in load carrying capacity, with the largest known capacity of 10,000 lb. While electrically powered carts are the best design for mass stability, they have other concerns and limitations.

Battery powered electric carts have also been manufactured and placed in to use. These weight carts are only slightly less stable than the electric carts powered by an umbilical cord, however they also are limited in load carrying capacity, and require frequent charging of the batteries. The loss of mass stability has been traced to the evaporation of water from the batteries which can, with poor maintenance, cause large mass errors. Newer sealed battery technology may provide a means of minimizing the effect of this water loss resulting in mass stabilities that equal that of the electrically powered weight carts.

The power source that has been most commonly used, also has the poorest mass stability record. These are liquid fueled weight carts. Many weight carts are powered by a liquid fueled internal combustion engine that generates motive power for the wheels through the use of hydraulic pumps and motors. Liquid fueled weight carts have many possible error sources.

- The fuel is consumed as the scale test progresses. The manufacturer of the most commonly used gasoline engine states a fuel consumption rate of approximately 15 lb/hr.
- The starter motor requires the use of a battery, usually the automotive style, which loses weight as the water evaporates, and requires occasional replacement,
- The hydraulic system has a large reservoir in which the fluid level must be maintained,
- The engine has a lubricating oil reservoir in which the level must be maintained, and
- The lube oil and the hydraulic fluid systems have filters that must be changed as part of routine maintenance.

These all contribute to tremendous potential instabilities in the weight cart mass, unless appropriate preventive actions are taken. Additionally, the lube oil and hydraulic fluid expand as they are heated by the engine and pump so that refilling the systems during or shortly after use is not possible. Evidence has shown that replacement battery weights can vary significantly. One user, trying to obtain a replacement battery of the same model and manufacturer as the one being replaced found a difference in weight of as much as 15 lb. All of these factors contribute to potential errors in the mass of the weight cart that must be corrected or minimized.

- 4.7 **Fuel Tank:** Handbook 44 Fundamental Considerations requires the error of a standard to be less than one third of the minimum applicable tolerance. For scale testing with a weight cart this would include the error in the mass of the weight cart and any weights used with the weight cart.

Liquid fuel density varies with temperature. With the six gallon fuel tank in use on some current weight carts, the weight of the fuel will vary approximately 1 lb for a 40 °F temperature change, assuming that the level is maintained at the reference mark. (It might be argued that this temperature change seems excessive, however it must be remembered that temperature changes are relative to the laboratory environment at the time of calibration. As the lab temperature will be approximately 70 °F, weight cart fuel temperatures below 30 °F and above 110 °F are possible.) As the largest proposed tolerance is 2 lb, this amount of variation due to just one of the many sources of error is excessive. Numerous options were discussed, from measuring the depth and temperature of the fuel and performing 'real time' calculations of the weight of the fuel, to using removable fuel tanks that would be disconnected at each scale test point. If the option using fuel depth and temperature was used, then the thermometers would require routine calibration, and a means of measuring the fuel depth would be required. Disconnecting the fuel tank at each scale test point would require repeatedly making and breaking fuel connections plus the constant need to re-start the engine. Each option considered has its own unique problems for the weight cart operator, but the current plan using a graduated 1 gallon liquid prover style tank and error weights, to compensate for fuel consumed, seemed to have the least impact on the scale testing process.

Fuel Specific Gravity @ 60 °F (API)	Weight (lb/gal)	Weight Change (lb/gal/°F)	Effect of 40 °F change per gallon (lb)	Change for 6 gallon tank (lb)	Change for 2 gallon tank (lb)
60 to 70	6.00	.0039	0.16	0.94	0.32

As a scale test is performed fuel is burned at a rate of approximately 15 lb per hour. If a test takes 15 minutes, the error in applied load will be approximately 3.75 lb or more than the allowable error due to standards (one third of the acceptance tolerance, 3.33 lb) on a 20 lb per division scale. There have been reports of weight cart operators filling the fuel tank at the start of the work day and calibrating scales until they ran out of fuel and were forced to refuel. Operation of a weight cart in this manner causes an error of approximately 36 lb which is unacceptable.

With the required 1 gallon fuel tank the error due to fuel density changes is drastically reduced to 0.16 lb for the a 40 °F temperature change and the maximum possible error due to not refilling the fuel tank is reduced to approximately 6.0 lb.

Knowing that the weight cart operator cannot maintain the fuel level at a specific reference level throughout the scale test, it was also decided to graduate the fuel tank in 0.5 lb increments and provide 0.5 lb error weights that the operator will add to the weight cart to

compensate for consumed fuel. This way, if the operator is being conscientious, the maximum expected error due to fuel will be less 0.5 lb under the worst possible condition.

The smallest known cross sectional area of a manufacturer installed weight cart fuel tank is approximately 28 square inches. With this small cross sectional area, a 0.25 inch variation in fuel height is equal to a change in weight of approximately 0.2 lb. With the largest fuel tank cross sectional area of 140 square inches, a 0.25 inch variation in fuel height is equal to a change in weight of approximately 1 lb. The motion and vibration of an operating weight cart cause constant sloshing of the fuel making reading the fuel depth indicator to a 0.25 inch variation in fuel height nearly impossible. Thus, a cross sectional area of 10 square inches was chosen, which results in a fuel tank height of approximately 24 inches. This also expands the range over which the fuel level can vary with minimal mass change, making fuel level changes more obvious to the operator.

- 4.8 **Hydraulic Fluid System:** A hydraulic fluid system is used to transmit power to the wheels on many weight carts. If so equipped, the hydraulic system must be a closed, system with tamper indicating seals on any component that might be routinely removed, e.g, the system fill cap, the filter, the system drain, etc. The hydraulic fluid, with a similar density to that of the fuel, must be in leak free system and must have seals so that routine 'topping-off' of the hydraulic system is not performed. Any maintenance requiring the addition of hydraulic fluid is cause for re-calibration of the weight cart. This is due mainly to the size and shape of the hydraulic reservoir which typically has a very large cross sectional area, making adjustment to a specific level very difficult. Many weight carts have hydraulic reservoirs so large that a 0.25 inch variation in height of the hydraulic fluid level would constitute a mass variation of several pounds. Additionally, as hydraulic fluid has a tremendous temperature expansion rate, the temperature at which adjustments in fluid level are made is quite critical.
- 4.9 **Engine Lubricating Oil System:** Engine oil also has a similar density to that of the fuel. Thus, engine oil levels are somewhat critical, though the actual impact of varying oil levels is difficult to calculate due to the odd shape of the engine crankcase. The oil level must be set at the manufacturer's recommended level after a minimum cool down period of four hours. This is to allow the oil to reach ambient temperature and to provide for a standardized drain down of the oil circulated through the engine. Routine service such as changing the oil and filter should be accomplished in conjunction with the calibration of the weight cart. Changing the oil and filter at times other than at calibration void the calibrated mass value of the weight cart, requiring re-calibration.
- 4.10 **Engine Exhaust:** Expelled exhaust gases may cause the generation of a force in the opposite direction to the opening of the exhaust pipe. Thus, exhaust outlets should be directed in a horizontal direction, as venting the exhaust gases in either an upward or downward direction may cause a force that will lead to inaccuracies in the applied scale load. This force has not been quantified, but changing to horizontal force vectors will eliminate the potential of scale influencing force generation.

- 4.11 **Tires:** There were two primary issues with weight cart tires. 1) Scale deck contact area loads, and 2) trapping of debris in the tire surface and transport of debris onto the scale deck. Both of these issues cause heated discussion in most any forum in which the subject is raised.

Due to the tremendous loads that are placed in the weight carts, up to 40,000 lb gross weight, the contact force of the weight cart tires to the scale deck can become damaging in certain circumstances. It is the desire of the Weight Cart Working Group that no scale test should damage the scale. Based on information provided by several scale manufacturers, the maximum exerted pressure should not exceed 200 psi. The number, diameter and width of tires on a weight cart should be selected based on the 200 psi maximum pressure.

Tire surfaces must be smooth (tread less) to avoid carrying debris in the treads and onto the scale. The average density of dirt or mud is approximately 120 lb per cubic foot. Even small amounts of dirt could cause an appreciable error in the load applied to the scale.

Several jurisdictions have stated that they need treaded tires to be able to reach the scale through the mud of a stockyard or through the snow and ice. Handbook 44, General Code deals with this issue, in section G-UR.2.3:

"G-UR.2.3. Accessibility for Inspection, Testing, and Sealing Purposes. - A device shall be located, or such facilities for normal access thereto shall be provided, to permit:

- (a) inspecting and testing the device;
- (b) inspecting and applying security seals to the device; and
- (c) readily bringing the testing equipment of the weights and measures official to the device by customary means and in the amount and size deemed necessary by such official for the proper conduct of the test.

Otherwise, it shall be the responsibility of the device owner or operator to supply such special facilities, including such labor as may be needed to inspect, test, and seal the device, and to transport the testing equipment to and from the device, as required by the weights and measures official.(Amended 1991)"

The use of tire chains or other means to gain access to a scale is permissible, as long as the weight cart configuration, plus any loaded weights, is exactly as it was at the time of calibration when it moves onto the scale deck.

- 4.12 **Wheel bearings:** It is the desire of the Weight Cart Working Group to minimize the maintenance of the weight carts and to thus minimize the possible variations in mass caused by the addition of lubricants. Some weight carts currently in service are equipped with a liquid lubricated wheel bearing unit similar to those used on large over-the-road trucks. These bearing units, because of the large volume of liquid lubricant that they may contain and possible variations in that liquid level, are not suitable for use on weight carts. Permanently lubricated bearing units are the most desirable, with bearings lubricated with a high temperature bearing grease being the second most desirable. Another possible means of bearing lubrication would involve the installation of grease fittings so that the bearing assembly can be maintained full of grease, with any excess expelled past the seals being removed as part of maintenance.

- 4.13 **Minimum Wheelbase and Track Dimensions:** This is simply a statement for the manufacturer to follow requiring that the loaded weight cart be designed so that it will not have a tendency to tip or upset during any normal scale testing process. This is influenced by the HB 44 accessibility requirements.
- 4.14 **Drainage:** Due to mass instability and mass errors caused by accumulated water on the weight cart surfaces, the weight cart must be designed to minimize this effect. Additionally, some current weight carts have been constructed of multiple layers of material so that water is trapped between the layers, causing mass errors and instabilities. The second part of paragraph 4.14 is designed to eliminate that error source.
- 4.15 **Weight Restraint:** The manufacturer must construct the weight cart so that the weights cannot dislodge during use, introducing a severe safety hazard.
- 4.16 **Weight Cart Transport:** The opinion of the weight cart working group is that one of the major potential sources of instability and error can be minimized by transporting the weight cart in an enclosed truck or covered by a tarp. Additionally, the weight cart must be securely fastened to the transporting vehicle.
- 4.17 **Lifting Attach Points:** There must be a means of lifting the weight cart for transport and the weight cart must remain approximately level when being lifted and not in contact with a supporting surface such as the ground or a truck bed floor.
- 4.18 **Adjustment Cavities:** Adjustment cavities must be provided to permit adjustment of the mass of the weight cart. More than one cavity is permitted to facilitate balancing of the weight cart when lifted by the lifting attach points. Due to the many components that could be changed as part of repair or maintenance, the total adjustment cavity volume must be capable of accepting up to 150 lb of adjustment material.

The adjustment cavities must be water tight to ensure that water contamination does not adversely affect the mass of the weight cart, and the adjustment cavities must be removable to permit easy installation or removal of adjustment material. The cavity openings and mounting mechanisms must be provided with a means to indicate tampering with the adjustment cavity.

The desired adjustment material is lead chunks or large lead shot. Fine lead shot is not recommended due to the large relative surface area which is more prone to mass instability caused by oxidation of the surface.

- 4.19 **Brakes: Service and parking:** Sufficient braking capacity must be installed to prevent a run away condition during normal use and when parked. The parking brake must be applied automatically when the engine is stopped and must maintain the fully loaded weight cart in a motionless condition under normal conditions of use.

- 4.20 **Directional controls:** To minimize confusion for the operator the weight cart controls should move in the direction in which the weight cart motion was desired, when the operator is standing in the normal operator's position on or near the weight cart.
- 4.21 **Battery:** Investigation into the battery designs available revealed that sealed lead acid batteries would be the most durable, long lived and mass stable option available at the time of the writing of this document. Other more exotic battery options are available, but result in increased cost and potentially shorter life cycles. When charged at the appropriate charging rate the sealed lead acid battery should have no loss of water mass due to evaporation, leading to a stable mass over time.
- 4.22 **Battery charging circuit:** The charging circuit must be so regulated that the battery mass is not adversely affected during normal routine use. Conversations with the manufacturers of the most common liquid fueled engines revealed that the standard charging circuit is sufficiently regulated to avoid over charging the sealed lead-acid batteries. The manufacturer of any engine used should be contacted for charging circuit specifications.
- 4.23 **Routine lubrication:** The weight cart lubrication points must be accessible when the weight cart is situated on a ground level surface. Lubrication points must be placed so that the operator is not forced to move under a suspended weight cart for maintenance. All lubrication points and places where lubricant might be expelled during use must be easily accessible to allow suitable cleanup, reducing any potential contamination issues.
- 4.24 **Electrical Power Connections:** The voltages and currents available to operate an electrically powered weight cart are sufficient to cause severe injury or death. For that reason all electrical connections must be UL approved and wiring must conform to local electrical code. Additionally, any connector that will remain on the weight cart during use, must be part of the calibrated mass of the weight cart. Conversely, any connector that is not part of the calibrated mass must be disconnected from the weight cart and removed from the scale deck during actual weighing operations, then re-connected for weight cart movement.
- 4.25 **Remote operation:** This section acknowledges that weight carts may be equipped for remote operation if desired, provided that such equipment does not cause the weight cart to fail to comply with the standard.

- 5 **Tolerances:** Weight carts are typically used in the testing of Handbook 44 Class III & IIIL scales with 20 lb or greater scale divisions, though there have been reports of testing scales with division sizes as small as 5 lb. NIST Handbook 44, Fundamental Considerations, requires that the error in the standards used be less than one third of the smallest tolerance to be tested. This requires that for acceptance testing of the first 500 divisions of a 20 lb/division scale, with an acceptance tolerance of 0.5 divisions, or 10 lb, the total error of the standards must be less than 3.333 lb. That seems like a fairly large error, but up to 1 lb of that error allowance can be taken up by the Class F weights being used. So only slightly more than 2 lb of error can be a result of the weight cart and other factors involved in the measurement. For a 5 lb/division scale, the acceptance tolerance in the first 500 scale divisions is 2.5 lb. One third of the tolerance is 0.8333 lb, typically making the use of a weight cart inappropriate for those calibrations.

The listed weight cart tolerances are a calculated value derived by dividing the acceptance tolerance of a scale on which such a weight cart might be used by three, and subtracting the tolerance of any NIST Class F weights that would be included at specific weight values. The lowest allowable value was then rounded down to the next lowest 0.25 lb increment. These calculations were performed at each of the NIST Handbook 44, Scales, Table 6, transition points for Class III and IIIL scales at $d = 5$ lb, $d = 10$ lb and $d = 20$ lb. Interestingly the smallest allowance for the weight carts is not at the lowest scale reading. It was instead at the $4000d$ indication, where the tolerance of the weights had a great impact.

- 6 **Verification requirements:** This section establishes the minimum verification requirements for the initial verification of the weight cart, a recommended initial calibration interval and a maximum calibration interval. The section also addresses the use of tamper indicating materials for all removable components of the weight cart.

Additionally, this section establishes a requirement for an "Inspection Checklist" for each weight cart. On that check list will be indicated any discrepancies that might render the weight cart unsuitable for testing scales.

In no way does this section of the document supercede local and state regulations that establish more strenuous requirements for weight cart verification.

- 7 **Test methods:** Weight carts will be calibrated IAW NIST Handbook 145, SOP 33, "Recommended SOP for Calibration of Weight Carts".
- 8 **Uncertainties:** Follows the guideline that the expanded uncertainty of the weight cart calibration must not exceed one-third of the allowable tolerance.
- 9 **User Requirements:** Weight cart use for the testing of large scales requires several items of documentation and the performance of routine maintenance at specific times.

- 9.1 **Use in combination with test weights:** Establishes the use of a weight cart alone or in combination with NIST Class F test weights.
- 9.2 **Weight Cart Maintenance:** Sets recommended times in the calibration cycle when the weight cart routine maintenance is to be performed depending on local requirements for "As Found" and "As Left" calibration values.
- 9.3 **Weight Cart Maintenance Logbook:** Establishes the requirement for a maintenance logbook that will be an integral part of a weight cart's traceability documentation. In the logbook will be the maintenance history of the weight cart, including details of any components replaced and routine maintenance performed.
- 9.4 **Inspection Checklist Verification:** Another part of the weight cart traceability chain. This document must be reviewed prior to scale tests to ensure that there are no issues with the weight cart that would make it unsuitable for the scale test.
- 9.5 **Weight Cart Cleanliness:** Any visible contamination is a possible error source and must be eliminated.
- 9.6 **Licensing of Weight Cart Operators:** This section is simply a preemptive notification to weight cart users that under U.S. Dept. of Labor, Occupational Safety and Health Administration (OSHA) guidelines for a "Powered Industrial Truck", the operators of weight carts MAY require licensing. This may also be true of operation of the weight cart transport hoist or boom, as an "Overhead Cranes or Hoist". The owning organization should contact their OSHA representative for a determination of licensing requirements.

As stated at the beginning of this document, weight cart use is a complex and emotional issue. It is hoped that this document answers some of the questions that the reader of NIST Handbook 105-8, "Specifications and Tolerances for Field Standard Weight Carts" may have concerning the rationale behind decisions made by the Weight Cart Working Group when writing this standards document.